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Michael T. Klare

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Climate Change Blowback: The Threats to Energy Security

Michael T. Klare

The role of energy in driving climate change is well understood. Far less understood, however, is the reciprocal effect of climate change on energy. Not all of these effects can be foreseen, but many are beginning to be perceptible. This essay looks at some of these perceptible effects, focusing on the relationship between climate change and the supply and demand for fossil fuels and renewable energies. The essay argues that while climate change may enhance energy production in some respects, its overall impact is likely to be negative unless far greater efforts are made to enhance the resilience of existing energy systems and shift reliance from fossil fuels to renewables.

Understanding the Reciprocal Effect

Most scientists now agree that climate change is occurring, that such change is being caused by the accumulation of heat-trapping greenhouse gases (GHGs) in the atmosphere, and that human activity is largely responsible for the emission of these gases. As indicated by the Intergovernmental Panel on Climate Change (IPCC) in its most recent (2014) assessment, "human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history."[1] Most scientists also agree that energy use—specifically, the production and consumption of fossil fuels such as oil, coal, and natural gas—generates a large share of the carbon dioxide (CO_2) and other GHGs that are causing climate change. According to the IPCC, CO_2 emissions from fossil fuel combustion and related industrial processes account for approximately two-thirds of all anthropogenic GHGs, with additional contributions coming from fossil fuel-related emissions of methane and nitrous oxide.[2] Given that global consumption of fossil fuels is expected to rise by 46 percent between 2010 and 2040, CO_2 and these other gases will continue to accumulate in the atmosphere and so further increases in world temperatures are widely considered inevitable.[3]

To slow the pace of climate change, policymakers are attempting to fashion an international accord aimed at increasing reliance on non-carbon sources of energy, especially renewable sources such as wind, solar, nuclear, and geothermal energy. Other proposals that incorporate limits on energy-related carbon emissions are already being developed by leading economies.

Michael T. Klare is a professor of Peace and World Security Studies at Hampshire College and director of the Five College Program in Peace and World Security Studies. He is the author of fourteen books, including, most recently, *The Race for What's Left.*

For instance, in November 2014, US president Barack Obama and Chinese president Xi Jinping announced a coordinated carbon-reduction initiative, under which the United States will reduce its CO_2 emissions to 26-28 percent below 2005 levels by 2025 and China will halt the growth in its CO_2 emissions by 2030 at the latest.[4] Under this plan, China has also committed to boost its share of non-carbon energy to around 20 percent by 2030.[5] Other countries are expected to announce similar measures at the twenty-first session of the Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) in December 2015.[6]

While the role of energy in driving climate change is well understood, the reciprocal effect of climate change on the availability and safety of global energy supplies—what might be called climate change blowback—is not. The IPCC only began to address the impact of climate change on energy availability in its 2014 Fifth Assessment Report (AR5) and its coverage was relatively limited.[7] It is evident, however, from this report and other scientific studies that climate change will affect the production, transportation, and consumption of energy in numerous and often harmful ways.[8] Climate change will alter the balance between demand and supply, create impediments in the development of some energy sources while favoring others, and interfere with the production and delivery of critical energy supplies. When combined, these outcomes are likely to hamper a country's ability to supply its citizens and industries with adequate supplies of energy. As indicated by the US Department of Energy (DoE) in its first comprehensive study of this problem, "Increasing temperatures, decreasing water availability, more intense storms events, and sea level rise will each independently, and in some cases in combination, affect the ability of the United States to produce and transmit electricity from fossil, nuclear, and existing and emerging renewable energy sources… [as well as] its ability to access, produce, and distribute oil and natural gas."[9]

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Climate change effects will also assume an ever-greater role in discussions of energy security. Until recently, concern over energy security—or the procurement of sufficient supplies of primary fuels to meet a nation's essential requirements—has largely focused on threats to the international flow of oil and natural gas arising from war, terrorism, and politically-motivated embargoes.[10] As is evident from the DoE report and others like it, however, a nation's ability to secure adequate supplies of energy will increasingly be strained by climate change. As will be shown below, climate change will alter both the demand and supply dimensions of the global energy equation, posing new and daunting challenges to the United States and other industrialized nations.

Climate Change and Energy Demand

The first aspect of this problem that merits attention is the matter of energy *demand*: Will climate change increase or decrease the demand for energy, or will its impact be neutral? If climate change results in increased demand, procuring adequate energy will become even more difficult; if it results in reduced demand, the problem will be diminished. What then can be deduced about the climate's future impact on demand?

Of the various impacts of climate change, the one that is most likely to affect energy demand is the continuing rise in average world temperatures. The global temperature has already risen by approximately 0.85 degrees Celsius (°C) since the onset of the industrial age, and, under existing trends, is projected to increase by another 1.5°C to 2.0°C between now and the end of the century.[11] These increases will have a dual impact on energy demand: in northern latitudes, warmer winters will result in a diminished demand for energy to provide heating, mostly supplied by oil, coal, and natural gas; whereas in tropical and temperate regions, hotter summers will result in an increased demand for energy, mostly electricity to power fans and air conditioning units. The question, then, is whether these opposing trends will cancel each other out or if one will prove dominant.

To address this question, the DoE examined a number of scenarios regarding potential energy demand in the United States under conditions of rising temperatures. These showed, by and large, that cities in northern parts of the country will see a net energy savings from reduced heating requirements, while cities in the south will experience augmented demand due to increased cooling requirements—with neither shift conspicuously outweighing the other.[12] But there is a caveat to this finding: as climate change advances, many parts of the country will see prolonged heat waves, in which daytime temperatures will exceed 95 degrees Fahrenheit (°F) for multiple weeks and generate massive demand for electricity to power air conditioners. This, combined with population growth and other factors, will place an immense burden on the nation's electricity supply that it might not be able to handle. As indicated by the DoE, "all scenario combinations indicate an increase in region-wide extreme temperature conditions of a severity associated with electricity shortages under the current configuration of the electrical power system and patterns of demand."[13]

The IPCC, in its 2014 report, sought to apply the same sort of analysis to energy demand at the global level. Like the DoE, it found that rising temperatures will result in both a diminished need for heating fuels in northern latitudes and an increased need for electricity in tropical and temperate zones. While acknowledging that it is impossible to determine with certainty whether the reductions in demand will cancel out the increases, it concludes that climate change "will *likely* increase the demand for energy in most regions of the world" (emphasis in the original).[14] This, it explains, is because of the geographic distribution of population and income growth. While little population growth is expected in the north, substantial population and income growth is expected in more southerly latitudes, producing a huge increase in demand for air conditioning. Indeed, the expected growth in global electricity demand for air conditioning is nothing short of astonishing, skyrocketing from an estimated 300 terawatt hours (TWh) in 2000 to approximately 4,000 TWh in 2050 and more than 10,000 TWh in 2100. This, in turn, will require a vast increase in electrical generation capabilities.[15]

Another demand-side aspect that neither the DoE nor the IPCC addresses is the energy requirement for climate change adaptation and reconstruction following major storm events. These requirements have become particularly salient in the aftermath of Hurricane Sandy in October 2012. According to a recent report from the US Army Corps of Engineers, at least six hundred and fifty thousand houses were either damaged or destroyed as a result of the storm.[16] Repairing and rebuilding these homes, along with all the other structures damaged or destroyed by Sandy, has required the expenditure of considerable energy. In the wake of Sandy, moreover, New York and New Jersey are contemplating major preventive measures, such as the construction of sea walls and barrier islands, which would further add to the demand for energy.[17] As climate change gains momentum, other regions of the world are likely to undertake similar measures. And while it is difficult to estimate the net energy requirements of such endeavors, they are certain to be substantial.

Climate Change and Energy Supply

As with demand, climate change will also have countervailing effects on the *supply* of energy. In recent years, energy providers have largely been able to increase production in tandem with rising demand. Total worldwide consumption from all available sources—fossil fuels, nuclear, and renewables—grew by 28 percent between 2003 and 2013, climbing from 9.9 to 12.7 billion metric tons of oil equivalent.[18] It remains to be seen, however, whether supply can sustain this pace of growth as the effects of climate change become more pronounced. Certain impacts of climate change could prove beneficial for supply: warming in the Arctic, for example, will make it easier to exploit the oil, coal, and natural gas deposited there; rising temperatures could facilitate the cultivation of crops for biofuels in some areas. Other impacts will cut both ways: shifting wind patterns will enhance the potential for wind power in some areas, and degrade it in others. By and large, however, climate change is likely to have more of a negative than a positive impact on the global supply of energy.

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Undergirding this negative outcome is energy's heavy reliance on water for multiple aspects of production, including the extracting and processing of fossil fuels, the operation of hydroelectric facilities, and the cooling of thermoelectric power plants. In 2010, energy production accounted for approximately 15 percent of global freshwater withdrawals, and its share is expected to expand in the years ahead in consonance with the projected increase in world energy consumption.[19] At the same time, climate change is expected to reduce the supply of water in many areas, to increase water temperatures, and to cause more frequent and prolonged heat waves—all of which will affect energy production in significant and often disruptive ways.[20]

By far the largest demand for water in the energy sphere comes from the cooling of steam-driven components of thermoelectric power plants, whether powered by coal, oil, natural gas, or nuclear energy. According to the US Geological Survey (USGS), thermoelectric plants were the largest single users of freshwater in the United States in 2005, consuming 140 billion gallons per day or 40 percent of all freshwater withdrawals.[21] Thermoelectric plants use a smaller share of water withdrawals on the international level, where agriculture plays the dominant role; however, the global demand for electricity is projected to increase by 50 percent between 2010 and 2035, and, with thermoelectric plants expected to generate most of this added electricity, energy's share of worldwide water use will grow appreciably.[22]

As climate change progresses, however, the availability of water for this purpose will become increasingly uncertain. Many rivers that provide water for power plant cooling are likely to experience reduced flows as a result of diminished precipitation, and even those supplies that remain available could prove too hot to allow for use in the cooling process. Already, state and federal regulators in the United States have had to suspend operations of some coal-fired and nuclear plants during hot and dry periods, and such suspensions are expected to increase in number and duration as climate change proceeds.[23] According to the DoE, "thermoelectric power generation facilities are at risk from decreasing water availability and increasing ambient air and water temperatures, which reduce the efficiency of cooling, increase the likelihood of exceeding water thermal intake or effluent limits that protect local ecology, and increase the risk of partial or full shutdowns of generation facilities."[24]

Large quantities of water are also needed for the extraction, processing, and transportation of fossil fuels. These uses include the injection of water into aging oil fields to increase their productivity (termed "enhanced oil recovery"); the injection of steam into underground bitumen deposits (tar sands, also called oil sands) to facilitate extraction; the processing or "upgrading" of tar sands to allow for their transportation and refining; the refining of crude petroleum into gasoline and other commercial products; the washing of coal to remove impurities prior to combustion; and, of particular note, the injection of water and assorted chemicals into underground shale formations to fracture the seams and facilitate the extraction of oil and natural gas (known as hydraulic fracturing, or hydro-fracking). These activities do not consume as much water as cooling operations in thermoelectric plants, but their utilization—especially by fracking—is growing, and often occurs in water-stressed areas.[25]

Because drillers typically can afford to pay more for available water, farmers, possessing less financial capacity, have often been forced to curb production in times of severe drought.

In Texas, for example, the extraction of oil from shale can require as much as thirteen million gallons of water to "frack" a well, with many thousands of wells needed to exploit a particular field or deposit. The growing pace of production there has placed increased stress on local water supplies, which are deemed wholly inadequate to meet all competing needs and are dwindling as a result of the state's prolonged drought.[26] Because drillers typically can afford to pay more for available water, farmers, possessing less financial capacity, have often been forced to curb production in times of severe drought. In some jurisdictions, moreover, water authorities have denied supplies to drillers in order to sustain local agriculture.[27]

Similar disputes are likely to arise in other parts of the world where water is scarce and hydro-fracking techniques are introduced. According to a study by the World Resources Institute, 38 percent of global shale gas resources are located in "areas that are either arid or under high to extremely high levels of water stress; 19 percent are in areas of high or extremely high seasonal variability; and 15 percent are in locations exposed to high or extremely high drought severity."[28] As climate change proceeds and the pace of hydro-fracking increases in these areas, the competition for water—especially in periods of drought—is bound to increase, producing political turmoil and, in some cases, outright violence.[29]

Climate Change and Renewable Energy

As climate change progresses, many policymakers hope to slow the pace of warming by reducing the consumption of fossil fuels and increasing reliance on renewable sources of energy. But while such sources produce fewer of the greenhouse gases that cause climate change, they are not immune to the reciprocal effect of climate change on energy. Like all other forms of energy, renewables will be affected by climate change, in both positive and negative ways.[30]

Hydroelectric Power

Hydroelectric power, the world's leading source of renewable energy, is particularly susceptible to the impact of climate change. Because the flow of water powers such facilities, any significant shift in precipitation—both in terms of quantity and seasonal variability—will have a corresponding effect on electrical output. Some areas that rely extensively on hydroelectricity, such as Canada, Scandinavia, and the southern cone of South America, may experience increased water flows as a result of climate change. In many temperate and tropical areas, however, water supplies are likely to diminish as a result of reduced rainfall, prolonged droughts, and the disappearance of glaciers. Generating facilities located on rivers that rely on snowmelt or glacial runoff to sustain flows during dry seasons will be at particular risk, as rising temperatures will reduce the ratio of snow to rain in annual precipitation and gradually eliminate many sub-Arctic glaciers.[31] As a result, the electrical output of many hydroelectric installations is likely to fall in the years ahead. For instance, in California, drying conditions are projected to result in a 20 percent decline in hydropower generation over the next sixty years. Other western states, including those that rely on the Colorado and Columbia rivers, are also likely to experience reduced hydropower generation.[32] Internationally, diminished rainfall is expected to curtail hydropower generation in many mid-latitude countries, including Brazil—the world's second-largest producer of hydroelectricity (after China) and the victim of a prolonged and brutal drought.[33]

Biofuels

Global warming—and its accompanying impact on water supplies—will also affect the production of biofuels. As in any agricultural endeavor, the growing of corn and other crops for use as energy feedstocks is highly dependent on favorable climate conditions. Global warming could increase the growing season in some areas used for growing such crops, and allow production in areas not previously usable for this purpose. At the same time, however, hotter temperatures and prolonged heat waves could reduce crop yields or destroy entire harvests.[34] As is true of fossil fuels, moreover, the production of biofuels requires large amounts of water—both for irrigating feedstock crops and for converting them into ethanol or biodiesel. Depending on soil conditions, annual rainfall, and other factors, the production of one gallon of corn ethanol requires anywhere from 17 to 239 gallons of water.[35] The production of biodiesel from algae can require even larger amounts of water: as much as three thousand gallons of water are needed to deliver one gallon of fuel.[36] Accordingly, future shortages of water could limit biofuel production just as much as fossil fuel production.

Wind and Solar

Lastly, climate change will likely have mixed effects on wind and solar energy supplies. In the case of wind, the DoE predicts shifts in the location and velocity of the most reliable wind currents, although the specifics of these shifts cannot yet be determined with any precision.[37] As for solar, the effects are a bit more complicated. Increased cloudiness in some areas—caused by higher rates of evaporation from lakes and oceans combined with the increased moisture-bearing capacity of warmer air—could reduce the output of solar collectors in many areas.[38] On the other hand, climate change could also make solar energy more practical in some areas, especially those expected to receive less rainfall. One solar technology that could face significant limitation as a result of climate change is concentrating solar power (CSP), a technique involving the deployment of hundreds or thousands of revolving mirrors used to focus solar energy on a column of liquid, which in turn generates steam for electric turbines. These large-scale facilities require as much, or more, water for cooling as thermoelectric power plants require. As a result, they, too, could be circumscribed by future water scarcities.[39]

Climate Change, Extreme Weather Events, and Energy Infrastructure

Aside from its effects on supply and demand, climate change will also pose a challenge to energy security through an increase in "extreme weather events" (EWEs) such as severe hurricanes and typhoons, intense bouts of precipitation, prolonged heat waves, and powerful storm surges. The frequency of EWEs has already increased in recent years, and scientists predict a further increase of such events in future years.[40] In 2014, the IPCC observed that "extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will *very likely* become more intense and more frequent" (emphasis in the original).[41] In the United States, the DoE predicts that high-rainfall events that today occur once every twenty years will occur once every four to fifteen years, depending on location.[42] Rising sea levels, combined with an increase in severe storms, will also increase the risk of massive storm surges like that produced by Hurricane Sandy in 2012. Events of this magnitude can damage and destroy refineries and drilling platforms, knock down power lines, force the shutdown of power plants and nuclear reactors, and otherwise disrupt the production and distribution of energy.[43]

All aspects of human life are at risk from EWEs, but energy is especially vulnerable because so many vital facilities—drilling platforms, refineries, power plants, oil and gas pipelines, transmission lines, and so on—are located in coastal areas or along rivers that are highly exposed to storm damage. The US Gulf Coast, an area frequently ravaged by hurricanes, houses approximately half of the nation's oil and gas production capabilities along with half of its refining capacity; additional refining and distributing infrastructure is located along the Atlantic and Pacific coasts. Many of these facilities have already been exposed to severe storm damage and are likely to experience further assaults in the future. Hurricane Sandy, for example, downed power lines, flooded electric substations, damaged or shuttered power plants, and deprived some eight million people of electric power. It also forced the shutdown of vital oil and natural gas facilities, including two oil refineries with a combined capacity of three hundred thousand barrels per day.[44] Hurricane activity has also inflicted enormous damage on the oil and natural gas infrastructure of the Gulf Coast: hurricanes Katrina and Rita in 2005 destroyed 115 offshore oil platforms and damaged 535 pipeline segments, causing a near-total shutdown of the Gulf's offshore oil and gas production.[45]

Among other types of EWEs, rising sea levels and intense flooding also pose a threat to many of the world's thermoelectric power facilities, which are typically located in coastal areas or along inland rivers in order to obtain water for cooling purposes. According to the IPCC, the global mean sea level rose by approximately 0.2 meters between 1901 and 2010, and is expected to rise by an additional 0.3 to 0.8 meters by the end of this century.[46] In California, twenty-five thermoelectric plants could be flooded by the end of the century, including key facilities in the Los Angeles and San Francisco Bay areas. Many power plants on the East Coast face a similar danger.[47] Inland power plants, like those on the Ohio, Missouri, and Mississippi rivers, could be threatened by rising flood waters associated with extreme precipitation events. In June 2011, for example, the Fort Calhoun Nuclear Generating Station in Nebraska was nearly inundated by floodwaters from the Missouri River; the plant had been shut down for repairs several months earlier, and the flooding delayed its return to service.[48] Pipelines and electric transmission lines are especially vulnerable to EWEs: damage or destruction of these facilities, according to the DoE, can occur as a result of "sea-level rise in coastal regions, melting permafrost in cold regions, floods washing away infrastructure, landslides triggered by high rainfall, and brushfires caused by heat waves or extreme temperatures in hot regions."[49]

Ensuring Energy Security

All of this suggests that climate change will pose an ever-increasing threat to energy security and must be accorded critical importance when developing and implementing local and national energy policies. Historically, concern over energy security arose from the dependence of many industrial powers, especially the United States, on oil and natural gas obtained from distant and sometimes unruly suppliers, notably the oil kingdoms of the Persian Gulf. Because these suppliers were regularly convulsed by war and rebellion, the pursuit of energy security came to mean the use of military means to ensure the survival of friendly producers and the safety of global supply routes.[50] Following the Islamic Revolution in Iran and the Soviet invasion of Afghanistan, for example, President Carter declared that any attempt to block the flow of Persian Gulf oil "will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force."[51]

Even with declining US reliance on imported oil—the result of increased production from domestic shale deposits—protection of the Persian Gulf oil flow remains a major US security mission. "Although America is steadily reducing our own dependence on imported oil," President Obama told the United Nations General Assembly in September 2013, we will continue to "ensure the free flow of energy from the region to the world."[52] But while it remains essential to enhance resilience to disruptions in the global energy flow caused by overseas conflicts, it is equally vital to enhance resilience to climate-related disruptions. With the world's energy infrastructure becoming ever more vulnerable to floods, droughts, and other EWEs, the safety and adequacy of global energy supplies is no longer assured. Accordingly, the concept of energy security should be broadened to encompass the effects of climate change and steps taken to both reduce the severity of climate change and enhance the survivability of critical energy systems.

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Decisions on future energy systems should be based, above all, on their potential role in abetting or slowing climate change, with a general bias in favor of low or zero-carbon technologies.[53] Such decisions should also factor in the reciprocal effects of climate change on energy, seeking to reduce as much as possible any given production or distribution system's vulnerability to storms, droughts, and other climate effects. This could mean choosing one type of production technology over another, or shifting the sites of proposed facilities to less exposed locations. In general, technologies requiring large amounts of water for their operation should be avoided in favor of systems using little water, and low-lying coastal and riverine areas should be avoided altogether when siting new facilities.[54]

Some efforts are already being made to foster such strategies. In the United States, for example, various measures are being taken to ensure that new thermoelectric plants employ technologies that minimize the use of water in cooling. Some drilling firms are also testing the reuse of fracking water so as to minimize withdrawals from local water supplies. Steps are also being taken to better protect critical energy infrastructure: the Army Corps of Engineers has built a floodwall to protect refineries in Texas City, Texas, and the city of New York has launched a "Special Initiative for Rebuilding and Resiliency" aimed, among other things, at better protecting the region's energy infrastructure from storm surges like that accompanying Hurricane Sandy.[55]

Unless far greater efforts are made in these directions, it is likely that climate change will pose an increasingly severe threat to the adequacy and reliability of global energy supplies. This threat will expand, moreover, in consonance with the increased emissions of GHGs from fossil fuel consumption. It would be ironic if the blowback effect of energy-related emissions on the future safety and adequacy of energy supplies proves to be one of the most damaging consequences of climate change for humans. This is all the more reason to hasten the transition to non-carbon sources of energy.

Notes

[1] Intergovernmental Panel on Climate Change (IPCC), C*limate Change 2014: Synthesis Report: Summary for Policymakers (Geneva: IPCC, 2014),* 1, retrieved at http://ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_SPMcorr2.pdf.

[2] Ibid., 4-5.

[3] US Department of Energy, Energy Information Administration (EIA), *International Energy Outlook 2013* (Washington, D.C.: EIA, 2013), Table A2, 181; IPCC, *Climate Change 2014: Synthesis Report.*

[4] John Podesta and John Holdren, "The US and China Just Announced Important New Actions to Reduce Carbon Pollution," The White House Blog, November 12, 2014, http://www.whitehouse.gov/blog/2014/11/12/us-and-china-just-announced-important-new-actions-reduce-carbon-pollution.

[5] Podesta and Holdren, "The US and China Just Announced Important New Actions to Reduce Carbon Pollution."

[6] See Associated Press (AP), "Deal Salvaged at UN Climate Talks in Peru," December 14, 2014, http://www.nytimes.com/aponline/2014/12/13/world/americas/ap-lt-peru-climate-talks.html.

[7] IPCC, Working Group II (WGII), *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (Geneva: IPCC, 2014), Chap. 10, 5-13, http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap10_FGDall.pdf.

[8] See US Department of Energy (DoE), *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather* (Washington, D.C.: DoE, July 2013).

[9] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather,* i.

[10] See, for example, Jan H. Kalicki and David L. Goldwyn, eds., *Energy and Security* (Washington, D.C.: Woodrow Wilson Center Press, 2005).

[11] IPCC, C*limate Change 2014: Synthesis Report,* 1, 10.

[12] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather*, 14.

[13] Ibid, 16.

[14] IPCC, WGII, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, Chap. 10, 12.

[15] Ibid.

[16] US Army Corps of Engineers, *North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk,* Main Report, January 2015, http://www.nad.usace.army.mil/Portals/40/docs/NACCS/NACCS_main_report.pdf.

[17] See ibid, 53-82.

[18] BP, *Statistical Review of World Energy,* August 2014 (London: BP, 2014), 40.

[19] International Energy Outlook (IEA), *World Energy Outlook 2012* (Paris: IEA, 2012), 514-17.

[20] IPCC, WGII, *Climate Change 2014: Impacts, Adaptation, and Vulnerability,* Part A, Chap. 3.

[21] US Geological Survey (USGS), *Estimated Use of Water in the United States in 2005* (Washington, D.C.: USGS, 2009), Table 2a, 7.

[22] IEA, *World Energy Outlook 2012,* 501-28, 552.

[23] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather,* 2-3, 22-25.

[24] Ibid, i.

[25] Ibid, 18-21.

[26] Ibid, 21. See also Joe Carroll, "Worst Drought in More than a Century Strikes Texas Oil Boom," Bloomberg News, June 13, 2011, http://www.bloomberg.com/news/articles/2011-06-13/worst-drought-in-more-than-a-century-threatens-texas-oil-natural-gas-boom/.

[27] See Paula Dittrick, "Drought Raising Water Costs, Scarcity Concerns for Shale Plays," *Oil & Gas Journal,* July 30, 2012, 20-21; Jack Healy, "For Farms in the West, Oil Wells Are Thirsty Rivals," *New York Times,* September 5, 2012.

[28] World Resources Institute (WRI), "Global Shale Gas Development: Water Availability & Business Risks," Key Findings, September 2014, http://www.wri.org/publication/global-shale-gas-development-water-availability-business-risks.

[29] See, for example, Jonathan Gilbert, "Protests Against Chevron Highlight Argentine Energy Woes," *Christian Science Monitor,* September 3, 2013; Brian Speglee and Justin Scheck, "Energy-Hungry China Struggles to Join Shale-Gas Revolution," *Wall Street Journal,* September 5, 2013.

[30] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather,* 11-12, 25-27.

[31] IPCC, WGII, *Climate Change 2014: Impacts, Adaptation, and Vulnerability,* Chap. 10, 7-8.

[32] Ibid, 26.

[33] Mackinnon Lawrence, "Severe Drought Hastens Hydropower's Slow Decline," *Forbes,* November 4, 2014, http://www.forbes.com/sites/pikeresearch/2014/11/04/severe-drought-hastens-hydropowers-slow-decline/.

[34] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather*, 11.

[35] Ibid, 27.

[36] Ibid.

[37] IPCC, WGII, *Climate Change 2014: Impacts, Adaptation, and Vulnerability,* Chap. 10, 8-9.

[38] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather*, 12.

[39] Ibid, 27.

[40] See IPCC, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (Cambridge and New York: Cambridge University Press, 2012).

[41] IPCC, C*limate Change 2014: Synthesis Report*, 12.

[42] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather*, 28.

[43] Ibid, 3, 28-35.

[44] Ibid, 30.

[45] Ibid, 3.

[46] IPCC, C*limate Change 2014: Synthesis Report*, 2, 13.

[47] California Electric Commission (CEC), *Estimating Risk to California Energy Infrastructure from Projected Climate Change* (Sacramento: CEC, 2012), http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf.

[48] See A. G. Sulzberger and Matthew L. Wald, "Flooding Brings Worries over Two Nuclear Plants," *New York Times,* June 20, 2011.

[49] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather*, 10.

[50] See Michael T. Klare, "Energy Security," in Paul D. Williams, ed., *Security Studies: An Introduction,* 2d edition (London and New York: Routledge, 2013), 535-51.

[51] Jimmy Carter, State of the Union Address, January 23, 1980, http://www.jimmycarterlibrary.gov/documents/speeches/su80jec.phtml.

[52] White House, Office of the Press Secretary, "Remarks by President Obama in Address to the United Nations General Assembly," September 24, 2013, http://www.whitehouse.gov/the-press-office/2013/09/24/remarks-president-obama-address-united-nations-general-assembly.

[53] IPCC, C*limate Change 2014: Synthesis Report*, 17-18.

[54] IPCC, WGII, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, Chap. 10, 7-10.

[55] DoE, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather,* 36-38. See also City of New York, *A Stronger, More Resilient New York* (New York: City of New York, 2013).